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U. S. ARMY AVIATION FATIGUE-RELATED ACCIDENTS, 1971-1977.(U)
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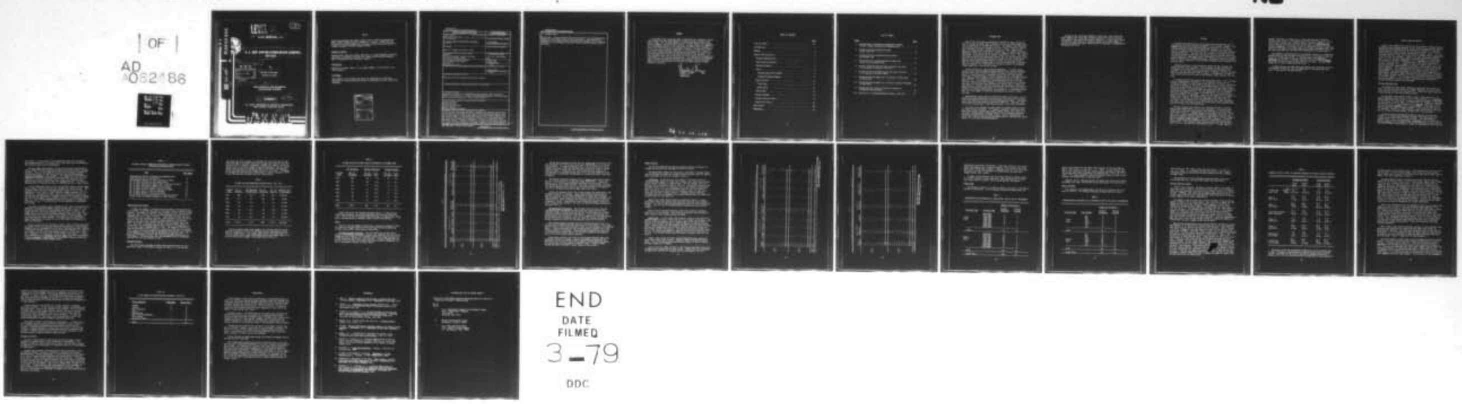

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An accident data survey was made to determine how frequently aviator crew fatigue may have contributed to US Army aviation accidents from 1971 to 1977. All accident reports in the US Army Agency for Aviation Safety (USAAAVS) data base were reviewed. Aviator fatigue was deemed to be a contributing factor in 42 rotary wing accidents which resulted in a total of 51 fatalities and 63 personnel injuries. Fatigue contributed to 10 fixed wing accidents, resulting in 3 fatalities and 5 injuries. This paper categorizes these fatigue related accidents by aircraft and mission type and by time of day and day of week of

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SUMMARY

An accident data survey was made to determine how frequently aviator crew fatigue may have contributed to US Army aviation accidents from 1971 to 1977. All accident reports in the US Army Agency for Aviation Safety (USAAAVS) data base were reviewed. Aviator fatigue was deemed to be a contributing factor in 42 rotary wing accidents which resulted in a total of 51 fatalities and 63 personnel injuries. Fatigue contributed to 10 fixed wing accidents, resulting in 3 fatalities and 5 injuries. This paper categorizes these fatigue related accidents by aircraft and mission type and by time of day and day of week of the accident. It also tabulates pilot activities prior to the accidents which promote the likelihood of pilot fatigue contributions. The personnel and equipment costs of these accidents to the Army are estimated, and the relative importance of such accidents to the total US Army aviation accident picture is assessed.

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INTRODUCTION

One of the most plaguing aeromedical problems in Army aviation is that of aviator fatigue. Many stressors of military flight operations act in combination to fatigue the aviator. For example, the Army pilot routinely encounters such stressors as heat, noise, vibration, blowing dust, hazardous weather, reduced visibility at night, exhaust from engines or weapons and labyrinthine stimulation. In combat operations additional stress may be caused by psychic elements such as fear, family separation, frustration and, of course, insufficient sleep.[1] Our present rotary wing training operations add to the list the increased stress found in low level and nap-of-the-earth flight and also flight while wearing various head-mounted sensors, displays or sighting systems. Some or all of these stressors may act on our aviators daily, and when they are combined with long hours of flying an aircraft in sustained flight operations, cause pilot fatigue.

Aviator fatigue is a multifaceted phenomenon. In rather encompassing terms the NATO AGARD Aerospace Medical Panel defined "fatigue" as being that state following a period of mental or bodily activity which is characterized by a lessened capacity for work and reduced efficiency of accomplishment, usually accompanied by a feeling of worrying, sleepiness or irritability and subjectively felt as a desire or need for rest. The immediate or short-term workload of flying the aircraft, the duration and frequency of work/rest periods in a 24-hour duty day, and the cumulative workload over several days or months all contribute to a pilot's state of alertness and operational efficiency.[2] Because of the multifaceted aspects of fatigue, it is very difficult to define pilot fatigue to everyone's satisfaction or to accurately determine its "true impact" on the safe performance of military flight missions.

Nevertheless, discussions of "aviator fatigue" continually arise in determining appropriate crew staffing ratios, planning military operations, and ensuring effective pilot performance and safety. Inevitably, these discussions get around to posing the question: "How many times has aviator fatigue been a contributing factor in aircraft accidents?"

For years pilot fatigue has been cited as a causal factor in many military aviation accidents. For example, isolated studies have estimated that aviator fatigue was a major causal factor in at least 7% of the early Vietnam combat accidents[3] and in 15% of European peacetime helicopter accidents over a 5-year period.[2] Karney reported that in Fiscal Year 1976 aircrew fatigue was identified as a contributing causal factor in 10 US Army aviation accidents.[4]

Because of the recurring interest in this topic, this report presents summary data on US Army aviation accidents for which accident investigators have identified aviator fatigue as a contributing factor. The relative contribution of these accidents to the total number of aviation accidents and their relative cost to the Army is estimated for the period 1971-1977.

METHOD

Accident data described in this survey were obtained from the US Army Agency for Aviation Safety (USAAAVS) at Fort Rucker, Alabama. The USAAAVS computerized accident data base was searched for all Army aviation accident reports which identified "fatigue" or "sleep deprivation" as possible contributing factors. These accidents were labeled "fatigue-indicated." The year 1971 was chosen as a starting point for the search because by that year the Army's aviation accident reporting system added pilot work-rest history information on most of the accident reports entered in the USAAAVS data base. The search covered accidents from all three components of the US Army worldwide--Active, Reserve, and National Guard.

Computer printouts of the technical reports of the "fatigue indicated" accidents were reviewed. The printouts included descriptive information on the accident, a narrative of events surrounding the accident, the accident investigation board's findings, relevant personal data for the crew involved in the accident, a chronological account of pilot activities 48 hours prior to the mishap, flight records, and cost data.

A twofold approach was used in analyzing these data. First, the two authors independently reviewed all the information listed for 134 "fatigue-indicated" accident reports and gave each an overall subjective rating as to whether or not he or she thought aviator fatigue may actually have contributed to the accident. These accidents were labeled "fatigue-related." No predetermined decision rules were established for making these categorizations. The two independent sets of judgments were then compared and an index of reliability was calculated to determine the degree of agreement. Next, the two judges met to agree on a common classification for those accidents which they had classified differently. Summary statistics of important facts concerning the accidents jointly judged to be "fatigue-related" were then calculated. The judges then rank order listed the factors which they weighted most heavily in making such determinations.

Second, relevant data from all 134 "fatigue-indicated" accident reports were summarized by descriptive statistics. The reports were categorized based upon crew personal data provided in each accident investigation report. Categorizations such as amount of sleep, flying hours, etc., were predominately based on information listed for the piloting crewmember who was identified in the report as having played a definite <u>primary causative role</u> in the accident sequence. In the US Army accident reporting system an aviator is identified as having a primary role in the accident "when the factor(s) which made the event most likely or inevitable are attributed to him."[5] In some reports

another individual, or factor (e.g., faulty maintenance or material failure), was listed as the primary cause while the fatigued aviator at the aircraft controls was listed as having a definite secondary role. Flight time and sleep data for this aviator were included in the statistical summaries. An aviator's role is considered secondary "when the factor(s) attributed to him were those which, when considered alone, did not cause the event but increased the likelihood of its occurrence."[5]

One important categorization in the accident reports is a subjective determination by Army accident investigator(s) as to whether or not the factors of "sleep deprivation" or "fatigue other" were definite or suspected contributors, or whether they were conditions merely present but which did not necessarily contribute to the cause. The data were summarized on these categorizations as well.

US Army aviation accident rates and relevant cost data were obtained from USAAAVS to show the relative importance of fatigue-related accidents in the overall accident picture.

RESULTS AND DISCUSSION

Many of the complexities involved in the accident investigating and reporting process became apparent in the review of the accident reports. Making post hoc determinations of the state of alertness or the "fatigued-state" of the pilots at the time of an accident is a difficult task during the actual accident investigation process itself. It is an even more difficult task in the analysis of accident reports some months or years after the accidents. Some of the most perplexing problems were: (1) All accident investigations did not produce the same types and amounts of required information. (2) Crewmembers did not always live to "tell the tale." (3) Occasionally, the figures obtained in witness statements (e.g., numbers of hours of sleep or work, etc.) did not coincide with those obtained by accident investigators piecing the puzzle together. (4) Fatigue was usually only one of multiple factors which appeared to have contributed to the causes of many accidents. Nevertheless, this detailed analysis of a fairly large number of accident reports provides a rough indication of the scope of the problem of Army aviator fatigue insofar as it can be determined through the study of accident reports. It, of course, does not tell us how many aviators, who were fatigued, carried out their flight missions successfully without becoming involved in an accident.

Fatigue Determinations

The USAAAVS accident report repository contained 134 accident reports listing sleep deprivation or fatigue indicators for one or more pilots during the years 1971 through 1977. Twenty-two reports were for fixed wing and 112 for rotary wing accidents.

The accident investigation reports listed "sleep deprivation" as being a definite causal factor in 4% of these accidents, as a suspected contributor in 19%, and as merely being a condition present at the time of the accident in 8% of them. "Fatigue-other" was listed as a definite contributor in 7% of the accidents, as a suspected contributor in 71% and as a condition present in 5% of the accidents. Sleep deprivation and fatigue-other were indicated together in the same accident for 17% of the cases. Generally, these indicators were attributed to the pilot who was listed as having played a primary role in the accident.

In the accident investigation process it was left to the investigator(s) to subjectively determine whether "sleep deprivation" or "fatigue-other" were factors in the accident. The indications of whether these factors were definite or suspected causes or merely conditions present, were assigned to the 134 accidents by a large number of different accident investigators or teams of investigators over a period

of 7 years. In the absence of any predefined guidelines for making those determinations, it is quite likely that there were differences in the criteria used by each investigator.

The two judges (the authors) in this survey classified 39% (52 of 134) of these "fatigue-indicated" accidents as actually being "fatigue-related." That is, the judges felt that there was enough evidence in the accident report to lead them to believe that fatigue may have actually contributed to the accident. This judgmental position can be regarded as differing significantly from the mere indication that fatigue was a condition "present" at the time of the accident and as being slightly more positive than the "suspected factor," but also as stopping short of the position that it "definitely" was a causal factor.

In the independent review of all the accident reports the two judges made a binary classification of each accident on a nominal scale: the accident either contained "fatigue-related" causes or it did not. A comparison of the 2 sets of classifications showed agreement on 119 of 134 reports, a proportion of 89%. When this figure was corrected to reflect only the proportion of agreement beyond that expected by chance, the index of agreement (Cohen's kappa)[6] was over .76 (confidence limits: $.65 < k < .85$). Perfect agreement would have resulted in a kappa coefficient of 1.00. A reliability of .76 can therefore be considered fairly high.

The types of accident report information the judges considered to be important in determining whether aviator fatigue was or was not a contributing causal factor in the accidents are listed in Table 1. Although the list rank orders the most useful factors at the top, the judges agreed that the scalar distance between items was slight. That is, for analysis of some accidents the ordering of the importance of some items may have been inverted. The judges usually considered a complex combination of several or all of the items of information in their deliberations.

One can see by the top listings of Table 1 that in the deliberations the judges relied on historical narrative descriptions of the accident sequences and the documentation of accident investigation board findings. If the board findings clearly called out "aviator fatigue" as a factor, the tendency was to accept that categorization of the accident. However, frequently the narratives "talked around" the subject. In these cases combinations of inadequate rest and sleep along with the presence of pilot judgmental flight errors in the accident sequence formed the criteria for making fatigue determinations.

TABLE 1

ACCIDENT REPORT INFORMATION CONSIDERED IN MAKING AVIATOR FATIGUE CONTRIBUTION DETERMINATIONS

ITEM	RANK ORDER
Investigation Board's Findings and Recommendations	1
Narrative Account of the Accident	2
Chronological Account of Crew's Previous 72 Hours	3
No. of Hours Duration of Last Sleep Period	4
No. of Hours and Mission Types Flown in the Last 24 Hours	5
No. of Hours Continuously Awake Prior to Event	6
No. of Hours and Type of Work in Last 24 Hours	7
No. of Hours Aviators Slept in the Last 24 Hours	8
No. of Hours Slept in the Last 48 Hours	9
No. of Hours Worked in the Last 48 Hours	10
No. of Hours Flown by the Aviators in the Last 30 Days	11
Aviator's Unit & Command Response to Board Findings	12

Army Aviation Accidents

To place the number of fatigue-related accidents into perspective, it is useful to consider the scope of the overall Army aviation accident problem. The number of accidents, the accident rate per 100,000 flying hours and their relative cost to the Army worldwide for each of the 7 calendar years are listed in Table 2.[7] There were 198 fixed wing and 1,077 rotary wing accidents, totaling 1,275 accidents during the period. The data show that there has been a steady decrease in the overall number of accidents and a slight decrease in the accident rate since 1971. Not shown in the table is the fact that the overall number of flying hours also decreased steadily from a high of 4,182,000 hours in 1971 to just under 1,500,000 hours in 1977. The number of fatalities, injuries and materiel cost varied as a function of the type of accident (e.g., type of aircraft, number of passengers and mission), the severity of the damage per accident and the escalation of materiel costs. It might also be useful to recall that the US Army began phasing out its involvement in Vietnam during 1971, and continued to do so throughout 1972 and into the early months of 1973.

Fatigue Accidents

The 134 fatigue-indicated accidents which occurred over the last 7 years are listed in the middle 2 columns of Table 3. It can be seen

that while the overall number of accidents declined from year to year, the percentage of accidents which were fatigue-indicated rose and fell variously, but in general, increased. Whether this general increasing trend is due to an actual change in the distribution of various causal factors for accidents or whether accident investigators have merely given increased attention to fatigue factors is not clear. The number of fatigue-indicated accidents constituted an overall average of 10.5% of all the aviation accidents over the 7-year period.

TABLE 2

US ARMY AVIATION WORLDWIDE ACCIDENT RATES, 1971-1977

Calendar Year	No. of Accidents	Acdt Rate per 100,000 Hours	No. of Fatalities	No. of Injuries	Materiel Cost ($ Thousands)
1971	556	13.3	325	501	$ 88,743
1972	217	9.1	136	184	33,055
1973	115	6.3	72	93	20,362
1974	113	7.2	7	77	14,472
1975	93	6.3	52	106	15,129
1976	90	6.2	28	94	22,539
1977	91	6.1	34	61	20,551
Total	1,275	8.8	654	1,116	$214,851

The 52 accidents which were judged to be "fatigue-related" constituted an average of 4.1% of all the Army aviation accidents worldwide for the 7-year period. This figure seems to be a good descriptor of a fairly stable year-to-year distribution which only ranged from 3.3 to 6.5% of the totals as shown in the right side of Table 3.

TABLE 3

US ARMY AVIATION FATIGUE RELATED ACCIDENTS BY CALENDAR YEAR

	All Accidents	Fatigue Indicated		Fatigue Related	
Calendar Year	No. of Accidents	No. of Accidents	% of Total	No. of Accidents	% of Total
1971	556	44	7.9	19	3.4
1972	217	20	9.2	8	4.1
1973	115	17	14.8	6	5.2
1974	113	12	10.6	5	4.4
1975	93	14	15.1	6	6.5
1976	90	16	17.8	4	4.4
1977	91	11	12.1	3	3.3
Total	1,275	134	10.5	52	4.1

Almost 12% of the 134 fatigue-indicated reports, 11 rotary and 5 fixed wing accidents, involved US Army Reserve or National Guard aircraft. Only 4 of the 52 fatigue-related accidents, 2 rotary and 2 fixed wing, involved Reserve or National Guard aircraft respectively.

Costs

Table 4 lists the number of fatalities, injuries and materiel costs for both the fatigue-indicated and the fatigue-related accidents by aircraft type, either fixed wing or rotary wing.

Fatigue-Indicated Accidents. The 112 fatalities and the 190 injuries in the fatigue-indicated accidents each represent over 17% of the respective total losses in all accidents during the 7-year period (112 of 654 fatalities and 190 of 1,116 injuries). The $27,724,000 total of materiel cost for these 134 fatigue-indicated accidents represents 13% of all the materiel losses for the 7 years.

TABLE 4

US ARMY AVIATION FATIGUE-RELATED ACCIDENTS AND THEIR COST BY CALENDAR YEAR

	Calendar Year	Fatigue-Indicated Accidents	Fatigue-Indicated Fatalities	Fatigue-Indicated Injuries	Materiel Cost ($ Thousands)	Fatigue-Related Accidents	Fatigue-Related Fatalities	Fatigue-Related Injuries	Materiel Cost ($ Thousands)
Fixed Wing	1971	3	0	3	$ 1,177	2	0	3	$ 1,158
	1972	3	2	0	140	2	0	0	40
	1973	4	2	0	2,229	1	0	0	14
	1974	3	0	0	31	1	0	0	23
	1975	3	3	2	286	2	3	2	281
	1976	3	3	0	221	1	0	0	103
	1977	3	3	0	160	1	0	0	24
	Total	22	13	5	$ 4,244	10	3	5	$ 1,643
Rotary Wing	1971	41	64	98	9,577	17	44	18	3,989
	1972	17	13	24	2,718	7	2	14	1,112
	1973	13	6	18	1,955	5	3	10	1,036
	1974	9	1	13	1,374	4	1	6	1,062
	1975	11	8	13	1,928	4	0	8	956
	1976	13	3	13	4,868	3	0	4	263
	1977	8	4	6	1,060	2	1	3	169
	Total	112	99	185	$23,480	42	51	63	$ 8,587
Grand Total	1971-1977	134	112	190	$27,724	52	54	68	$10,230

NOTE: Difference in the totals of Tables 4 and 5 is due to the rounding of dollar amounts.

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The fatigue-indicated accident rate for fixed wing aircraft was 1.04 per 100,000 overall fixed wing flying hours (22 accidents in 2,111,900 flying hours). In terms of materiel cost, 9 of the aircraft in the 22 fatigue-indicated fixed wing accidents were classified as total losses. These accidents included the loss of two significantly higher cost aircraft (OV-1's), accounting for over 73% of the total materiel costs ($3,091,600 of $4,244,000) attributable to fatigue-indicated fixed wing accidents.

The fatigue-indicated accident rate for rotary wing aircraft overall was .91 (112 accidents in 12,302,400 rotary wing hours). Eighty-four percent of all the fatigue-indicated accidents for the period (112 of 134) involved rotary wing aircraft. The rotary wing accidents accounted for 88% of the fatalities, 97% of the injuries and 85% of the materiel loss in all fatigue-indicated accidents over the 7 years.

Thirty-five percent (39 of 112) of the fatigue-indicated rotary wing accidents occurred in Vietnam. These losses were not attributed directly to hostile fire but were categorized as combat zone accidents. They accounted for 58 deaths (34 of them in a single CH-47 accident), 96 injuries (50 of them in another CH-47 accident) and over $10.5 million in materiel losses. Twenty-one of these Vietnam accidents resulted in total losses of the aircraft. All but 1 of the 39 accidents occurred in the years 1971-72.

Fatigue-Related Accidents. The 54 fatalities resulting from the "fatigue-related" accidents for both fixed and rotary wing aircraft combined account for over 8% (54 of 654) of all the fatalities in Army aviation accidents during the 7-year period. The fatigue-related injuries made up over 6% (68 of 1,116) of all injuries for the same period. The $10.23 million in materiel cost for these 52 fatigue-related accidents represents 4.8% of all the materiel losses for the period.

The fatigue-related accident rate for fixed wing aircraft was .47 accidents per 100,000 fixed wing flying hours (10 accidents in 2,111,900 hours); and for rotary wing aircraft it was .34 (42 accidents in 12,302,400 hours). Eighty-one percent of the fatigue-related accidents (42 of 52) involved rotary wing aircraft. These accidents accounted for over 94% of the fatalities, almost 92% of the injuries and 85% of the materiel loss in all the fatigue-related accidents.

Thirty-three percent (14 of 42) of the fatigue-related rotary wing accidents occurred in Vietnam. These 14 accidents accounted for 40 fatalities (34 of them in the CH-47 accidents already mentioned above), 16 injuries and over $4,160,000 in materiel costs. Eight of these Vietnam accidents resulted in total losses of the aircraft.

Model Aircraft

The fatigue-indicated and fatigue-related aviation accidents are categorized according to the model aircraft in Table 5.

The approximate number of flying hours, the overall accident rates, and the fatigue-indicated and fatigue-related accident rates for each of these same model aircraft are listed in Table 6.

Fixed Wing. On the basis of the numbers of aircraft in the inventory and the number of flight hours logged, four fixed wing aircraft are of special interest to today's Army: the OV-1 Mohawk, the T-42 Cochise, the U-8 Seminole, and the U-21 Ute. The overall accident rate for each of the first 3 of these was over 10 per 100,000 flying hours while for the U-21 it was considerably lower at only 5.0 (Table 6). Pilot fatigue did not stand out as an accident factor for any one of these four aircraft (Tables 5 and 6). Although fatigue-indicated accident rates varied somewhat, the fatigue-related rates for these four aircraft were all less than 1.0.

Some of the fixed wing aircraft are regularly flown by a single pilot while others are rarely flown with less than two pilots aboard. However, 8 of the 22 (36%) fatigue-indicated accidents were single pilot flights. Four of the 10 fatigue-related accidents were single pilot flights.

Nine of the 22 fatigue-indicated fixed wing accidents involved a total loss of the aircraft. Four fixed wing aircraft were classed as total losses in the fatigue-related accidents.

Rotary Wing. In the rotary wing category, seven of the eight helicopters listed in Tables 5 and 6 are still of interest to the Army. The OH-13 and OH-6 helicopters are no longer found in the Active Army inventory, but the OH-6 is flown in many USA Reserve and National Guard units. Table 6 shows that the overall accident rates for the AH-1 Cobra and the OH-6 Cayuse were over 20, while that for the OH-13 Sioux was over 10 per 100,000 flying hours. The fatigue-indicated accident rates for all the rotary wing models of interest to the active Army were 2.0 or less. The fatigue-related accident rates of interest were all less than .7.

Twenty-seven of the 112 (24%) fatigue-indicated rotary wing accidents were single pilot flights. Twenty of these involved the OH-58 Kiowa. Ten of the fatigue-related accidents (eight of them in the OH-58) were single pilot flights.

Sixty of the 112 (54%) aircraft in the fatigue-indicated rotary wing accidents were categorized as total losses. These total loss accidents included 29 of the 54 UH-1 Iroquois utility helicopters, 20 of 31

TABLE 5

US ARMY FATIGUE-RELATED AVIATION ACCIDENTS AND THEIR COST BY MODEL OF AIRCRAFT, 1971-1977

		Fatigue-Indicated				Fatigue-Related			
	Aircraft Model	Accidents	Fatalities	Injuries	Materiel Cost ($ Thousands)	Accidents	Fatalities	Injuries	Materiel Cost ($ Thousands)
Fixed Wing	O-1	1	0	1	$ 19	-	-	-	$ -
	OV-1	3	2	0	3,124	1	0	1	1,059
	T-42	6	6	0	270	2	0	0	43
	U-1	1	0	2	166	1	0	2	166
	U-3	1	0	0	6	-	-	-	-
	U-6	4	2	2	222	2	0	2	120
	U-8	2	3	0	140	2	3	0	140
	U-10	1	0	0	14	1	0	0	14
	U-21	3	0	0	285	1	0	0	103
	Total	22	13	5	$ 4,246	10	3	5	$ 1,645
Rotary Wing	AH-1	14	4	8	3,226	4	2	4	,636
	CH-47	3	40	50	4,413	1	34	0	1,675
	CH-54	1	2	2	3,025	-	-	-	-
	OH-6	4	1	1	188	-	-	-	-
	OH-13	2	0	2	21	2	0	2	21
	OH-58	31	12	31	2,683	14	3	16	1,165
	TH-55	3	0	3	79	-	-	-	-
	UH-1	54	40	88	9,846	21	12	41	4,090
	Total	112	99	185	$23,481	42	51	63	$ 8,587
Grand Total	1971-1977	134	112	190	$27,727	52	54	68	$10,232

NOTE: Difference in the totals of Tables 4 and 5 is due to the rounding of dollar amounts.

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TABLE 6

US ARMY AVIATION ACCIDENTS DURING THE YEARS 1971-1977 AS A FUNCTION OF AIRCRAFT MODEL

	Model Aircraft	No. of Flying Hours (Thousands)	Accidents	Overall Acdt Rate Per 100,000 Hrs	Fatigue Indicated Accident Rate	Fatigue Related Accident Rate
Fixed Wing	O-1	199	28	14.1	.5	-
	OV-1	209	25	11.9	1.4	.5
	T-42	220	24	10.9	2.7	.9
	U-1	29	11	37.6	3.4	3.4
	U-3	61	5	8.2	1.6	-
	U-6	204	19	9.3	2.0	1.0
	U-8	343	35	10.2	.6	.6
	U-10	11	6	54.7	9.1	9.1
	U-21	399	20	5.0	.8	.3
	Others	437	25	5.7	-	-
	Total	2,112	198	9.4	1.04	.47
Rotary Wing	AH-1	699	146	20.90	2.0	.6
	CH-47	484	32	6.6	.6	.2
	CH-54	64	5	7.8	1.6	-
	OH-6	470	129	27.4	.9	-
	OH-13	54	7	13.0	3.7	3.7
	OH-58	2,223	183	8.2	1.4	.6
	TH-55	937	79	8.4	.3	-
	UH-1	6,714	444	6.6	.8	.3
	Others	657	52	7.9	-	-
	Total	12,302	1,077	8.8	.9	.3
Grand Total		14,414	1,275	8.8	.9	.4

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observation helicopters (18 OH-58's, 1 OH-6 and 1 OH-13), 5 of 14 AH-1 attack helicopters, all 4 cargo helicopters (CH-47 Chinook and CH-54 Tarhe) and 2 TH-55 Osage trainers. Fourteen of 21 UH-1's, 8 of 14 OH-58's and 3 of 4 AH-1's involved in fatigue-related accidents were categorized as total losses.

In terms of the relative cost of aviator fatigue accidents (Table 5), the OV-1 materiel losses were high. Both the human and materiel costs were high for the AH-1, CH-47, OH-58 and UH-1 accidents.

Time of Day

The fatigue accidents are listed in Table 7 according to the time of the day of occurrence. The 112 fatigue-indicated accidents were not

TABLE 7

FATIGUE-RELATED ACCIDENTS AS A FUNCTION OF TIME OF DAY OF OCCURRENCE

Aircraft Type	Period of Day	Number of Accidents: Fatigue Indicated	Number of Accidents: Fatigue Related
	0400-0659	-	-
	0700-0959	2	1
Fixed Wing	1000-1259	3	1
	1300-1559	2	-
	1600-1859	6	2
	1900-2159	8	5
	2200-0059	1	1
	0100-0359	-	-
Total		22	10
	0400-0659	7	3
	0700-0959	19	3
Rotary Wing	1000-1259	22	7
	1300-1559	22	7
	1600-1859	17	7
	1900-2159	9	4
	2200-0059	11	9
	0100-0359	5	2
Total		112	42
Grand Total		134	52

evenly distributed over the eight 3-hour periods of the day shown in Table 7 (Chi-square = 25.90, df = 7, $p < .005$). In fact, 69% of them (93 of 134) occurred during the 12-hour period from 0700 to 1900 hours (Chi-square with Yates correction for discontinuity = 19.41, df = 1, $p < .005$). This seems reasonable since the greatest number of Army flying missions are accomplished in daylight hours.

However, the 52 "fatigue-related" accidents were evenly distributed throughout the eight time periods listed (Chi-square not significant).

Day of the Week

The accidents are categorized by the day of the week of the occurrence in Table 8. The fatigue-indicated accidents were not evenly

TABLE 8

FATIGUE-RELATED ACCIDENTS AS A FUNCTION OF DAY OF THE WEEK OF OCCURRENCE

Aircraft Type	Day of Week	Number of Accidents: Fatigue Indicated	Number of Accidents: Fatigue Related
	Sun	2	0
	Mon	2	2
Fixed	Tues	3	2
Wing	Wed	5	0
	Thurs	3	2
	Fri	5	3
	Sat	2	1
Total		22	10
	Sun	13	7
	Mon	9	3
	Tues	19	8
Rotary	Wed	24	7
Wing	Thurs	22	10
	Fri	16	5
	Sat	9	2
Total		112	42
Grand Total		134	52

distributed over the 7 days of the week (Chi-square = 15.3, df = 6, .01 < p < .025). It can readily be seen that most of the fatigue-indicated accidents occurred on the four busiest work days, Tuesday through Friday.

The occurrence of the 52 fatigue-related accidents was evenly distributed over the 7-day week (Chi-square not significant).

Aviator Activity Levels

Table 9 lists the mean, the median, and the range of the number of hours the aviators spent in various activities prior to the accidents. These data were obtained for inclusion on accident reports in a variety of ways. Commonly, they came from statements made by the pilots involved, from interviews with witnesses and from chronological histories pieced together by accident investigators.

The numbers cited are those for aviators who were listed as having played a primary role in the accident. Row 1 of Table 9 summarizes the number of hours of flight time the aviators logged in the 24 hours immediately preceding the accidents. The grand mean for the pilots involved in all 134 fatigue-indicated accidents was 4.0 flight hours in the last 24 hours. The standard deviation (SD) was 2.8. The average number of flight hours for the pilots in the 52 fatigue-related accidents was slightly higher with a mean of 4.8 and a SD of 3.2 hours. The large standard deviations and the broad ranges cited in the table describe the wide variability of these measures. These data demonstrate that one cannot infer aviator fatigue solely by knowing the number of flight hours the pilot logged in the last 24 hours.

When making determinations about fatigue factors influencing aviator performance, it is important to consider both the pilot's duty and off-duty activities for several days prior to the accident. Rows 2 through 7 of Table 9 summarize work and sleep activities for the 48 hours preceding the accidents. The hours listed in rows 2 and 3 represent military duty hours. On the average, the pilots worked over 11 hours in the last 24 hours and they worked over 20 hours in the last 48. Again, the variability in these data was high. Twenty percent of the pilots (26 of 129) worked 15 or more hours during the 24 hours preceding the accidents. Fifteen of these pilots were involved in accidents judged to be fatigue-related. As the ranges indicate, there were some pilots whose chronological histories listed a small number [illegible] hours prior to the accident. Unfortunately, the descriptions of [illegible]ff-duty activities were not always complete. Some were very sp[illegible], for example, listing "4 hours of reading" and some were quite va[illegible] as "I went out for the evening." There was not enough consistenc[illegible] this portion of the data to present a useful measure by which to gauge the impact of some of the off-duty activities on these pilots.

TABLE 9

AVERAGE ACTIVITY LEVELS OF AVIATORS INVOLVED IN FATIGUE-RELATED ACCIDENTS

		Fatigue-Indicated		Fatigue-Related	
		Fixed Wing	Rotary Wing	Fixed Wing	Rotary Wing
	Avg =	4.1 hr	3.9	5.4	4.7
Flight Time	Median =	4.5	3.3	6.1	4.6
Last 24 Hr	Range =	(0-8 hr)	(0-16.5)	(0-8)	(0-16.5)
		11.0	11.4	12.3	13.4
Work in		11.0	11.0	12.3	13.0
Last 24 Hr		(7-15)	(2-21)	(10-15)	(3-21)
		20.0	20.0	20.7	23.0
Work in		20.0	20.0	21.5	22.0
Last 48 Hr		(7-24)	(2-40)	(20-24)	(6-40)
		11.3	8.5	13.1	10.6
Continuously Awake		12.4	8.0	13.8	11.0
Prior to Event		(3-16)	(1-19)	(5-16)	(2-19)
		7.1	6.6	7.1	5.4
Sleep in		7.8	6.5	7.7	5.0
Last 24 Hr		(4-9)	(2-11)	(4-8)	(2-10)
		14.6	13.9	14.4	12.6
Sleep in		15.8	14.0	15.9	13.0
Last 48 Hr		(4-18)	(8-21)	(4-18)	(8-21)
		6.9	6.0	7.1	4.7
Duration of		7.2	6.5	7.5	4.3
Last Sleep		(4-9)	(2-11)	(4-8)	(2-11)
		29.3	46.9	32.7	43.0
Flight Time		24.0	31.3	38.5	27.8
Last 30 Days		(0-62)	(0-138)	(7-55)	(0-133)

How long a pilot was continuously awake prior to the accident (Row 4, Table 9) played an important part in making fatigue factor determinations. One-third of the pilots involved in fatigue-indicated accidents (45 of 129 case histories which included data on this question)

had been awake for more than 12 hours. More importantly, 56% (28 of 50) of the pilots in the accidents judged to be fatigue-related had been awake longer than 12 hours; 12 of these pilots were awake longer than 15 hours; 7 of them longer than 17 hours.

The mean number of hours of sleep which pilots reported they obtained in the 24 and 48 hours prior to the accident (Rows 5 and 6, Table 9) is not very informative by itself. The averages approximate the number of hours of sleep obtained by many adults on a regular basis. Examining the number of sleeping hours for each pilot on an individual basis was not much more informative. One fixed wing pilot slept only 4 hours in a 48-hour period. However, the next lowest amount of sleep for the fixed wing pilots was 13 hours of sleep in a 48-hour period. Of the 105 rotary wing aviators for whom data were available, only 12 slept less than 4 hours in the last 24 hours and only 4 slept less than 8 hours in the 48 hours preceding the accidents. The data for the number of hours of sleep obtained during the 48 hours preceding the accidents clearly do not stand by themselves as fatigue determiners.

Some of the explanations for the seemingly nonutility of knowing the number of hours of sleep in the last 48 hours become apparent in an examination of the data on the duration of the last sleep (Row 7, Table 9). Twenty-five percent of the pilots (31 of 126) involved in the fatigue-indicated accidents slept for less than 4 hours their last "sleep session" prior to the accidents. Forty-two percent of the pilots (20 of 48) in the fatigue-related accidents slept less than 4 hours at a time. Thus, although pilots were getting a total of 6 or more hours of sleep per 24-hour period, many were not getting sleep of adequate duration in a single sleep session. Their case histories cite "nap taking" frequently.

Man's sleep cycles usually alternate periods of light dreaming sleep necessary for psychological restoration with deep sleep needed for physiological recovery. One such cycle generally lasts on the order of 90 minutes.[8] It is very possible that the short duration sleep periods of many of the pilots involved in these accidents prevented them from getting enough "restful" sleep prior to the accidents.

The total number of flying hours a pilot accumulates during a 30-day period is usually considered in the interest of determining if chronic fatigue is involved (Row 8, Table 9). There has not been universal agreement as to how many hours per month a pilot should be allowed to fly. The policies regarding such limits have changed several times with increasing attention to combat fatigue losses. During the 1971-73 involvement in the Vietnam conflict the Army aviators who accumulated 90 flight hours in a 30-day period were to be monitored closely by both the unit commander and the flight surgeon. A certificate of the crewmember's

fitness to continue accumulating flight time above 110 hours had to be signed by the flight surgeon and the unit commander and placed in the crewmember's flight records.[9] The present Army Regulation, AR 95-1,[10] says that "in combat, 140 hours per 30-day period has been considered a safe and effective performance ceiling and as a general rule aviators flying beyond 90 hours in a 30-day period must be observed frequently by a flight surgeon."

Sixteen percent of the pilots (21 of 134) involved in fatigue-indicated accidents, 7 in the fatigue-related category, accumulated over 90 flight hours in the 30 days preceding the accident. All 21 of these accidents were in rotary wing aircraft, and all occurred in Vietnam. Since the Vietnam involvement, only 2 of 67 pilots accrued over 70 flight hours in the 30 days prior to their accidents. It seems that tracking the number of flight hours per 30-day period is not a very sensitive measure of aviator fatigue in peacetime operations.

Not shown in Table 9 are the data on missed meals. Irregularity of food ingestion and lack of hot meals may influence a pilot's capacity for sustained optimal performance and contribute to conditions of fatigue.[3] Seventeen percent of the pilots (23 of 134) in the fatigue-indicated accidents missed one or more meals during the workday of the accident. Nineteen percent of the pilots (10 of 52) involved in the fatigue-related accidents missed at least one meal.

Analysis of Errors

One of the implications of the search for pilot fatigue is that fatigue will somehow cause a pilot to modify his performance. Performance changes may come in the form of slower reaction times, lapses of attention, errors of omission or increased variability in performance of known tasks.[11]

Categorizing accidents into those which involve detrimental pilot performance changes is almost as difficult as making pilot fatigue determinations. Without elaboration as to how the decisions were made, 42 of the 52 fatigue-related accidents were categorized as involving pilot errors. Table 10 lists these pilot error situations. As examples of errors of omission and lapsed attention, two pilots landed fixed wing aircraft with the gear up, and one pilot failed to place the prop lever in position prior to takeoff. Four pilots allowed their aircraft to run out of fuel. Slowed reaction times were apparent in late attempts to take corrective action in degrading autorotation conditions. Variability in performance was exhibited in sloppy hovers and landings which resulted in accidents.

TABLE 10

PILOT ERROR IN FATIGUE-RELATED ACCIDENTS, 1971-1977

Error Situation	Fixed Wing	Rotary Wing
Takeoff	1	1
Landing	4	8
Fuel Starvation	2	2
Hover	-	4
Autorotation	-	5
Poor Visibility/Weather	-	5
Wire Strikes	-	6
Low Level Flight	-	4
Total	7	35

CONCLUSIONS

Pilot fatigue is very likely to have been a contributing factor in 4.1% of all US Army aviation accidents worldwide from 1971 through 1977. Fifty-four fatalities and 68 injuries resulting from 52 fatigue-related accidents account for over 8% of all fatalities and for over 6% of all injuries suffered during the period. The $10.23 million in materiel losses for the fatigue-related accidents amounted to over 4.8% of all materiel losses during the 7 years.

Accident rates of .47 fixed wing and .34 rotary wing accidents per 100,000 flying hours were calculated for fatigue-related accidents indicating that fixed wing fatigued aviator accidents were slightly more frequent during the 7-year period. However, the 42 rotary wing accidents accounted for over 94% of the fatalities, almost 92% of the injuries and 85% of the materiel losses in the fatigue-related accidents.

Fatigue-related accidents did not occur in one model aircraft more than in another. However, one-fourth of the helicopter accidents (10) occurred in single pilot flights and 8 of these involved the OH-58 Kiowa. Sixty percent (25 of 42) of fatigue-related rotary wing accidents resulted in a total loss of the aircraft.

Fatigue-related accidents were evenly distributed throughout the 24-hour day and the 7-day week.

The chronological history of a pilot's activities prior to an accident was used in determining whether or not pilot fatigue contributed to the accident. The duration of a pilot's last sleep and the number of hours he had been continuously awake prior to the accident were the indicators most relied upon. By themselves, the number of flight hours logged and the number of hours slept the 24 hours prior to the accident were not adequate determiners of pilot fatigue. An assessment of all the information contained in the case history was integrated into the rest of the accident investigation report in making determinations of fatigue factors.

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